Collection of Design Data: Site Characterization for Permeable Reactive Barriers

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Permeable reactive barriers (PRBs) for the restoration of contaminated ground water are no longer innovative. PRBs have evolved from innovative to accepted, standard practice, for the containment and treatment of a variety of contaminants in ground water. Like any remedial technology, the decision to use PRBs will be conditioned by the nature of the natural system, the target contaminants, and treatment objectives. In the past 7 years, more than 70 sites have implemented this technology to treat chlorinated solvent compounds, fuel hydrocarbons, and various inorganic contaminants in ground water. As with any technology used to treat or extract contaminants in the subsurface, successful implementation will be contingent on effective site characterization, design and construction.

As with any ground-water remediation technology, adequate hydrogeologic characterization must be done to understand flow patterns and the distribution of the contaminant plume. This is particularly important for PRBs as the treatment system is immovable or passive yet must intercept or capture the contaminant plume for effective treatment. Information to be obtained includes advective velocity parameters such as the gradient, the hydraulic conductivity, porosity, and other parameters collected as part of a hydrogeologic characterization program. It is also important to understand temporal changes in flow direction and flux due to processes such as recharge, pumping of adjacent wells or other disturbances. Many sites have observed changes in flow direction by as much as 30 degrees from time to time.

In addition to the hydrology, the stratigraphy and lithology of the site is important to understand and will dictate effective PRB design. If a low permeability layer exists at the site, the PRB can be keyed into this layer. If it does not exist, then a “hanging wall” design must be chosen which may add to the uncertainty of plume capture. If the site has low permeability layers through which the PRB must be constructed, care must be taken during construction to avoid smearing of such layers. This could impact hydraulic contact between the formation and the reactive media. A thorough understanding of site stratigraphy is especially important or helpful in choosing a particular construction method. Use of sheet piling to construct a reactive “gate” may not be a good choice where low permeability layers exist because of the smearing potential.

Characterization of contaminant concentrations in four dimensions is required for successful implementation of a PRB. In addition to knowledge of the plume in the x-y-z directions, it is also imperative to understand variability in plume shape and direction over time. Plumes deviate in direction and location over time and may change shape due to attenuation, degradation, dilution, recharge and other natural and anthropogenic induced disturbances.

PRBs are often located within plumes. This requires some understanding of the impact of construction on plume behavior, both up and down gradient of the barrier. Will hydraulic contact between the plume be and reactive media be established or will the plume be diverted by the barrier? If located below an impermeable surface structure such as a parking lot, will the surface be repaved immediately or will recharge be allowed to occur over the PRB? Will this affect plume behavior or change of location within the aquifer? Some understanding of natural attenuation processes at the site is important in being able to interpret the subsequent response of the natural system to the presence of the PRB. This is most often manifested in trying to estimate how long the down gradient aquifer will require to achieve cleanup goals. How long will it take the contaminants located down gradient of the barrier to flush out of the sediments or degrade naturally?

Geochemical characterization of sites for PRBs is important for optimizing the design and performance of a PRB and for predicting longevity. The lifetime of a PRB will depend on the hydrogeochemical nature of the site, flow rate and contaminant flux among other factors. It is known that high carbonate waters, high nitrate waters, high dissolved organic carbon waters or waters with generally high total dissolved solids will have shorter life expectancies than what might be considered “typical” or “average” composition waters. Decreased life expectancy may be caused by competition for reaction sites, loss of reactive sites due to rapid corrosion or fouling, or precipitation of inorganic minerals due to changes in geochemistry caused by the presence of the reactive media with subsequent loss of permeability.

If zero-valent iron is the reactive media, corrosion reactions together with mineral precipitation will eventually result in loss of permeability and/or reactivity resulting in decreased performance to the point where performance goals are no longer met. Long-term performance studies have documented decreased reactivity at some sites over time as well as loss of porosity, which can affect residence time of contaminants in the reactive media. For inorganic contaminants, such as chromium and arsenic, removal capacities have been calculated for zero valent iron PRBs. These capacities can be quickly reached if waters are rich in species that compete for reaction sites.

Microbiological impacts are important to understand in order to better predict how long PRB systems will remain effective. The presence of a large reservoir of iron coupled with abundant substrate availability supports the metabolic activity of iron-reducing, sulfate-reducing, and/or methanogenic bacteria. These populations may have either beneficial or detrimental effects on system performance. Enhanced biodegradation of contaminants is possible where growth is stimulated by the presence of the reactive media, but biofouling may lead to permeability reduction within the reactive media or immediately up gradient.

Disclaimer

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